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VARIATION OF ORAL AND NASAL STOPS BY ENGLISH AND JAPANESE LEARNERS OF THAI

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Abstract
A categorical variability constraint-based analysis (Boersma & Hayes 2001) accounts for oral and nasal stop acquisition in three different positions by English and Japanese learners of Thai. Homorganic nasals take place at the intermediate level where two or more surface forms are selected as optimal candidates. Both aspirated and voiced stops also occur, avoiding an unaspirated onset in almost equal frequencies. To account for variation of Thai stops, GLA, a stochastic OT approach is adopted for constraint reassessment rather than standard OT. In the initial state of the grammar, markedness constraints outrank faithfulness constraints for beginners. Markedness and faithfulness constraints overlap for intermediate learners exhibiting variation. At the advanced stage, faithfulness constraints were higher ranked because both English and Japanese learners are able to master Thai oral and nasal stops. The analysis proposed in the paper yields more accurate results than a categorical analysis.

Keywords: Gradual Learning Algorithm, Second Language Phonological Acquisition, Free Variation, Homorganic Nasals, Thai Oral and Nasal Stops, Thai as a Second Language
ISO 639-3 codes: eng, jpn, tha

1 Introduction[1]

This study investigates the acquisition pattern of oral and nasal stops produced by English and Japanese speakers of Thai in word-initial, word-medial and word-final positions. The proposal here is that the observations can be accounted for by categorical variability via stochastic OT by Boersma & Hayes (2001). This paper is organized as follows: in section 1, Thai, English and Japanese oral and nasal stops are introduced as well as their prosodic structures. In section 2, the methods of how the data are collected are discussed, then the way that English and Japanese learners of Thai acquire oral and nasal stops are presented along with generalizations. Section 3 presents the framework, a stochastic OT approach and in Section 4 I propose the analysis for the observation that variation on oral and nasal stops were found in both word-initial and word-final position and the nasal stops are not faithful word-medially in the Japanese group. Rather, they surface as homorganic nasal stops getting the place of articulation from the adjacent oral stops. Some remaining issues are addressed and the paper is concluded in section 5.

1.1 Thai, English and Japanese Oral and Nasal Stops

Oral stops in Thai are phonemically characterized as a series with a three-way contrast between aspirated, voiceless and voiced stops, with a gap for voiced palatal or velar stops, as shown in (1). English, on the other hand, distinguishes only voicing and aspiration and phonemically lacks voiceless unaspirated stops as shown in (2). They only occur as allophones after the initial [s] yielding [sp], [st] and [sk], and in intervocalic onsets of unstressed syllables in American dialects. In word final position they are unreleased and therefore

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unaspirated. Japanese also has a two-way contrast for oral stops. It has voiced stops in word-initial and word-medial position. As for voiceless stops, studies offer mixed results regarding whether voiceless stops are either unaspirated (Selkirk 1984, Tsujimura 1996) or "moderately aspirated" (Shimizu 1996). Riney (2007) proposes that Japanese voiceless stops are neither unaspirated nor aspirated, rather they fall between the two categories, with evidence coming from VOT measurements.

(1) Thai oral and nasal stops

	bilabial	alveolar	palatal	velar
stop	p p^h b	t t^h d	c c^h	k k^h
nasal	m	n		ŋ

(2) English oral and nasal stops

	bilabial	alveolar	velar
stop	p^h b	t^h d	k^h g
nasal	m	n	ŋ

(3) Japanese oral and nasal stops

	bilabial	alveolar	palatal	velar	uvular
stop	p b	t d		k g	
nasal	m	n	ɲ	ŋ	N

The data in (4) to (9) show the distribution of Thai, English and Japanese oral and nasal stops, respectively. In Thai, all stops can occur word-initially; however, word-final position only allows unreleased voiceless stops /p/, /t/ and /k/, as shown in the data (4) and (5). English has a two-way contrast between voiced and voiceless in both word-initial and word-final position as in (6) and (7); however, the aspirated series are allophones of the voiceless stops that only occur in onset position. In Japanese (8) to (10), all stops occur in onset positions and in the environments of geminates, rendaku (sequential voicing) and postnasal obstruents. However, there are no oral stops in word-final position.

(4) Thai oral stops in word-initial position

Unaspirated	ปา [paː] 'throw'	ตา [taː] 'eye'	กา [kaː] 'crow'
Aspirated	พา [p^{h}aː] 'take'	ทา [t^{h}aː] 'paint'	คา [k^{h}aː] 'obstruct'
Voiced	บ่า [baː] 'shoulder'	ด่า [dàː] 'scold'	-

(5) Thai oral stops in word-final position

Unaspirated	*[pàp]	*[tàt]	*[tàk]
Aspirated	*[pràp^h]	*[tàt^h]	*[kàk^h]
Voiced	*[pràb]	*[tàd]	-
Unreleased	ปรับ [pràp̚] 'fine'	ตัด [tàt̚] 'cut'	กัก [kàk̚] 'confine'

(6) English oral stops in word-initial position

Aspirated	[**p^h**ɪn]	'pin'	[**t^h**ɪn]	'tin'	[**k^h**ɪn]	'kin'
Voiced	[**b**et]	'bet'	[**d**et]	'debt'	[**g**et]	'get'

(7) English oral stops in word-final position

Coda neutralization	[sɪ**p**]	'sip'	[sɪ**t**]	'sit'	[sɪ**k**]	'sick'
	[la**b**]	'lab'	[la**d**]	'lad'	[la**g**]	'lag'

As mentioned before, Japanese does not contrast aspiration in any position. It is only found on the allophonic level in inter- or intra-speaker variation shown in data (8) and (9).

(8) Japanese oral stops in word-initial position

Unaspirated	[**p**o.ka.ri]	'lightly'	[pi.**t**a.ri]	'fit'	[**a.k**a.ri]	'red'
Aspirated	[**p^h**at.to]	'suddenly	[**t^h**o.ki]	'time'	[**k^h**a.me]	'turtle'
Voiced	[**b**en.ri]	'comfort'	[**d**o.ko]	'where'	[**g**in.ko]	'bank'

Data (9) show free variants of the unaspirated series across Japanese speakers.

(9) Japanese oral stops in word-medial position

Unaspirated	[k^{h}a**p**.**p**a]	'raincoat'	[k^{h}i**t**.**t**e]	'stamp'	[k^{h}e**k**.**k**a]	'result'
Aspirated	[k^{h}a**p^h**.**p^h**a]	'raincoat'	[k^{h}i**t^h**.**t^h**e]	'stamp'	[k^{h}e**k^h**.**k^h**a]	'stamp'
Voiced	[ta**m**.**b**o]	'dragonfly'	[ka**n**.**d**e]	'chewing'	[ri**ŋ**.**g**o]	'apple'

In Thai, nasal stops can occur in both word-initial and word-final positions. English nasals have direct counterparts, except that velar nasal stops in English cannot occur in word-initial position.

(10) Thai nasal stops /m/, /n/, /ŋ/ in word-initial and word-final position

ม้า	[**m**á:]	'horse'	ต้ม	[tô**m**]	'to boil'
นา	[**n**a:]	'rice field'	นอน	[nɔ:**n**]	'to sleep'
งู	[**ŋ**u˥]	'snake'	ย่าง	[yâ:**ŋ**]	'to roast'

(11) English nasals /m/, /n/ in word-initial and /m/, /n/, /ŋ/ in word-final position

[**m**i:t]	'meet'	[t^{h}i:**m**]	'team'
[**n**o:ʊt]	'note'	[ʧɪ**n**]	'chin'
*[ŋi:p]		[sɪ**ŋ**]	'sing'

On the other hand, Japanese nasals contrast only two places of articulation, /m/ and /n/, manifesting only in word-initial position. When moraic, nasals are homorganic with the following onset. If there is no following consonant, a moraic uvular nasal is produced, as shown in (12).

(12) Japanese nasals /m/, /n/ word-initially, word-medially and word-finally

[**m**e]	'eye'	[sa**m**.**p**o]	'take a walk'	*[ho**m**]	
[**n**e]	'price'	[be**n**.**t**o]	'lunch box'	*[ho**n**]	
*[ŋe]		[ge**ŋ**2.**k**i]	'fine'	*[ho**ŋ**]	
				[ho**N**]	'book'

1.2 Syllable Structures

Language types with respect to rhythm are typically classified as stress-timed, syllable-timed or mora-timed (Nesper, Shuka & Mehler 2011). Stress-timed languages like English and Thai have a kind of two-beat rhythm (strong-weak-strong-weak or weak-strong-weak-strong etc.). Syllable-timed languages like Spanish, for example, don't have the strong-weak pattern with each beat having the same weight. Mora-timed languages like Japanese differ in that moraic consonants increase the duration, the same way a vowel would. So while English has moras and assigns them to nasals in codas, it doesn't increase the weight (the duration), for example, [su:] 'sue' and [su:n] 'soon'. But in Japanese [ko] 'child' and [koŋ] 'dark grey', the rhyme in the latter word has a longer duration. In both the English and the Japanese examples the second word has an extra mora which is the nasal coda, so there is no difference in the mora assignment. However, the mora-timed language like Japanese sees an increase in the duration; the stress-timed language like English (and also Thai) does not.

2[ŋ] is an allophone of /g/ in Japanese, that surfaces intervocalically; for example, nagasaki [na. ŋa.sa.ki] 'the city of Nagasaki'.

(13)	CV	C V V	C V N	N
	|	| |	| |	|
	μ	μ μ	μ μ	μ

The maximal word in Thai has a C(C)V(V)(C) syllable template. / can also occur as a coda in Thai, but only with short vowels. CV/ syllables were treated as open CV syllables by Abramson (1962) even though most accounts note the presence of a glottal stop coda in these syllables (Gandour 1974b; Morén & Zsiga 2006). Morén & Zsiga (2006) argue that there is an epenthetic glottal stop in which its distribution is predictable, but it is not contrastive, satisfying a requirement for Thai syllables to be bimoraic.

English has a slightly more complex template of (C)(C)(C)V(V)(C)(C)(C). The difference in timing units must be taken into consideration when dealing with English, Japanese and Thai phonology. As suggested by Ito & Mester (2003), Japanese takes both the mora and syllable as prosodic units. When Japanese speakers learn languages of syllable-timed rhythm, they tend to transfer their own mora-timed rhythm. For example, they may prefer to preserve the nasal instead of deleting it due to a mora preservation constraint like saN “three”, saN-niN “three people”. Namely, a mora has a weight value that must be preserved in the structure. A mora deletion would be strictly banned and must be avoided at all costs (Yamane 2013, Ohata 2004, Ito & Mester 2003). However, deletion takes place in consonant clusters. The evidence is from loanwords like mi.lu.ku. in “milk”. In this study, we show that mora preservation is the case for Japanese learners of Thai.

2. Methods

2.1 Experimental Design

A list of stimuli was classified into three groups of Thai words. The stimuli words were made up of 14 CVC monosyllabic words and 24 CVC.CVC bisyllabic words, for a total of 38 words, the first of which are 8 words with initial oral stops, varying in the laryngeal modification (voiceless unaspirated, aspirated, voiced). The second set consists of 24 bisyllabic words, with word-medial oral or nasal stops. The final set consists of 6 words with initial and final nasal stops.

Picture prompts were used to elicit the stimuli words in order to avoid any orthographic influence. The participants thus looked at the pictures and were questioned in Thai as shown in (14). In case some prompts would not lead to the production of the target form, there was a back-up of more ‘familiar stimuli word’ pictures. However, this study excluded pictures that participants did not recognize or for which they had forgotten the corresponding words. Data were elicited in three different days with slightly different questions, but with the same target responses to allow for individual variation. Overall, they were elicited three times, 20-30 minutes each time. Participants took 15 to 30 seconds to respond to each stimuli.

(14)	Q:	nî:	p^hâ:p	ʔarai	k^há
		this	*picture*	*what*	*polite marker*
		‘What is this picture?’			

	A:	námta:
		water-eye
		tear

Tables 1-3 below illustrate 38 experimental word stimuli in total. Stimuli monosyllables are shown in Table 1, in which voiceless unaspirated, aspirated and voiced stops were used in word-initial position.

***Table 1:** Word-initial unaspirated oral stops*

oral onset	Experimental word stimuli		
/p, t, k/	[puː] 'crab'	[tôm] 'boil'	[kàj] 'chicken'

***Table 2:** Word-initial aspirated oral stops*

oral onset	Experimental word stimuli		
/pʰ, tʰ, kʰ/	[pʰrik] 'chili'	[tʰːɔ̂t] 'fry'	[kʰon] 'people'

***Table 3:** Word-initial voiced oral stops*

oral onset	Experimental word stimuli	
/b, d/	[bòn] 'complain'	[dom] 'smell'

Bisyllables were constructed with the first syllable containing a nasal stop coda and oral stop onset. These stimuli provided a phonological context where nasal stops were adjacent to oral stops as shown in table 4.

***Table 4:** Nasal stops preceding oral stops in word-medial position*

word-medial	Experimental word stimuli		
/m+p, pʰ, b/	[tampuː] 'crab salad'	[sămpʰaw] 'Chinese boat'	[să:mbaj] 'three leaves'
/m+t, tʰ, d/	[námtaː] 'tears'	[ramtʰaj] 'thai dance'	[să:mda:w] 'three stars'
/m+k, kʰ/	[tômkáj] 'boil chicken'	[tômkʰáj] 'boil egg'	
/n+p, pʰ, b/	[kinpuː] 'eat crab'	[wanpʰút] 'Wednesday'	[tɔːnbàj] 'afternoon'
/n+t, tʰ, d/	[wɛ̂ntaː] 'eyeglasses'	[tɔːntʰîaŋ] 'at noon'	[făndiː] 'good night'
/n+k, kʰ/	[kinkàj] 'eat chicken'	[tɔːnkʰâm] 'at night'	
/ŋ+p, pʰ, b/	[sɔ̌ːŋpiː] 'two years'	[sɔ̌ːŋpʰan] 'two thou:sand'	[sɔ̌ːŋbaj] 'two leaves'
/ŋ+t, tʰ, d/	[tɛ̀ŋtua] 'get dressed'	[tʰuŋtʰaːw] 'socks'	[sɔ̌ːŋdaːw] 'two stars'
/ŋ+ k, kʰ/	[kaːŋkeːŋ] 'pants'	[tʰaːŋkʰâw] 'entrance'	

Tables 5 and 6 show the opposite of Tables 1 to 3. Nasal stops occur in word-initial and word-final position.

***Table 5:** Word-initial nasal stops*

nasal onset	Experimental word stimuli		
/m, n, ŋ/	[mǎː] 'dog'	[nûat] 'massage'	[ŋuː] '*snake*'

***Table 6:** Word-final nasal stops*

nasal coda	Experimental word stimuli		
/m, n, ŋ/	[tam] 'pound'	[nɔːn] 'sleep'	[yâːŋ] 'grill'

2.2 Participants

30 participants were recruited from students who were studying at a Thai language institute in Bangkok. All reported having no background in other languages. The first 15 were native English speakers from different countries (The United States, Canada, England and Australia). The other 15 spoke Japanese as their native language. They took a speaking test arranged by the school, and the results were used as criteria for classifying them into 3 different levels based on their scores. They were placed into two groups as follows: E/J[3] beginners, 5 E/J intermediate and 5 E/J upper intermediate learners. Beginners received a score of less than 39 percent, while intermediate ones received a score ranging between 40-79 percent. Upper intermediate learners received a score of 80 percent or higher. Time spent in Thailand and at school was also taken into account. Those who took Thai lessons for less than 60 hours and stayed in Bangkok for less than 3 months at the time of the study were grouped as beginners. Those who took Thai lessons between 60 and 120 hours and stayed in Bangkok from 3 to 6 months were grouped as intermediate learners, and those who took Thai lessons for over 120 hours and stayed in Bangkok for at least 6 months were grouped as upper intermediate learners.

***Table 7:** Participants*

Participants	Scores of standardized Thai language exam	Number of studying hours	Length of stay in Thailand (Months)
E/J1 – E/J5	≤39	≤60	≤ 3
E/J6 – E/J10	40 – 79	61 – 120	3 – 6
E/J11 – E/J15	≥80	≥120	≥ 6

2.3 Recording

There were 38 distinct target words in the study. This included 8 oral stops in word-initial position, 6 nasal stops in word-initial and word-final position, and 24 words with a nasal preceding an oral stop in word-medial position. Each participant produced each stimulus 3 times on 3 different days, for a total of 114 tokens, with a total of 3,420 stop consonant tokens. Tone errors were not considered in the evaluation. The experiment was carried out at the language lab in a university. On each trial, participants were presented with a slideshow, with each picture in the center of the screen of a monitor. They responded by uttering the word over a headset microphone connected to a computer**.**

2.4 Data Accuracy

All target forms were first annotated by a trained Thai phonologist and phonetician and double checked by the author. The audio file was analyzed using the acoustic program Praat (Boersma & Weenink, 2016), with the phonetic transcriptions being compared and corrected if discrepancies were found. The results presented in this section represent the frequencies of occurrence of oral and nasal stops in all positions out of the total collected.

Table 8 illustrates the accuracy of production rate of unaspirated stops in word-initial positions of English participants of Thai. The three levels were categorized using the criteria mentioned. The mean percentage of correct responses to the stimuli of the beginner proficiency group was the lowest. The accuracy was twice as high in the intermediate proficiency group and slightly higher again in the upper intermediate group.

3 E abbreviates for English speakers and J for Japanese speakers.

***Table 8:** Accuracy of production of word-initial unaspirated stops by 15 English speakers of Thai*

Word	Beginners E1-5						Intermediate E6-10						Upper Intermediate E11-15					
	1	2	3	4	5	Avg	6	7	8	9	10	Avg	11	12	13	14	15	avg
[puː]	0	0	0	0	0	0	0	0	0	0	0	0	66.66	100	33.33	100	66.66	73.33
[tôm]	0	0	0	0	0	0	0	0	0	0	0	0	66.66	66.66	33.33	100	66.66	66.66
[kàːj]	0	0	0	0	0	0	33.33	33.33	33.33	33.33	33.33	33.33	66.66	100	66.66	100	66.66	79.99

***Table 9:** Production variation in word-initial unaspirated stops by English speakers of Thai*

Word Stimuli		Beginner (E1-E5)	Intermediate (E6-E10)	Upper Intermediate (E11-E15)
Word-initial	/puː/	[buː] 100%	[pʰuː] ~ [buː] 33.34% 66.66%	[puː] ~ [buː] 73.33% 26.67%
	/tôm/	[dom] 100%	[tʰom] ~ [dom] 66.66% 33.34%	[tom] ~ [dom] 66.66% 33.34%
	/kàj/	[kʰàj] ~ [gàj] 86.67% 13.33%	[kʰàj] ~ [kàj] 66.66% 33.34%	[kàj] ~ [kʰàj] 79.99% 20.01%

***Table 10:** Production variation in word-initial unaspirated stops by Japanese speakers of Thai*

Word Stimuli		Beginner (E1-E5)	Intermediate (E6-E10)	Upper Intermediate (E11-E15)
Word-initial	/pu˥/	[puː] 100%	[puː] 100%	[puː] 100%
	/tôm/	[tomɯ] ~ [tom] 79.99% 20.01%	[tomɯ] ~ [tom] 66.66% 33.34%	[tom] 100%
	/ka∃j/	[kàj] 100%	[kàj] 100%	[kàj] 100%

After calculating word inaccuracy as reported in the tables above, variant forms were pronounced by English participants. In the beginning stage, speakers produced voiced stops [buː] and [dom] 100% of the time for unaspirated voiceless stops. In the intermediate stage, speakers generated variedly both aspirated and voiced. However, in the upper intermediate stage, speakers correctly produce a higher percentage of unaspirated voiceless stops. Japanese participants, on the other hand, had no problem in producing the correct form of unaspirated voiceless stops in Thai.

***Table 11:** Production of nasal stop variation in word-initial position by English speakers of Thai*

Word Stimuli		Beginner (E1-E5)	Intermediate (E6-E10)	Upper Intermediate (E11-E15)
Word-initial	/mǎː/	[máː] 100%	[máː] 100%	[mǎː] 100%
	/nûat/	[nùat] 100%	[nûat] 100%	[nûat] 100%
	/ŋuː/	[nuː] 100%	[nuː] ~ [ŋuː] 66.66% 33.34%	[ŋuː] ~ [nuː] 79.99% 20.01%

***Table 12:** Production of Nasal stop variation in word-initial position by Japanese speakers of Thai*

Word Stimuli		Beginner (J1-J5)	Intermediate (J6-J10)	Upper Intermediate (J11-J15)
Word-initial	/mǎː/	[mǎː] 100%	[mǎː] 100%	[mɔːp] 100%
	/nûat/	[nuat] 100%	[nuat] 100%	[nuat] 100%
	/ŋuː/	[guː] ~ [nuː] 66.66% 33.34%	[guː] ~ [ŋuː] 66.66% 33.33%	[ŋuː] 100%

When comparing nasal stops onsets produced by English and Japanese participants, Table 11 and 12 show similar results in that both groups produced bilabials and alveolars with 100% accuracy of the time, whereas both groups produced velars at a lower frequency. Intermediate and upper intermediate English speakers produced velars as alveolars at the rate of 66.66% of the time and 20.01% of the time respectively. As can be seen in Table 12, the Japanese group had more variation than the English group as exemplified in [**g**uː], [**ŋ**uː] and [**n**uː] and produced velar nasals as oral stops at the same error rate of 33.33%. English speakers, however, are more faithful to nasal sounds.

The Japanese group also exhibited variation in word-final position of alveolar nasal at all levels, as shown in table 13. The beginner group produced the incorrect from [nɔːnɯ] 79.99% of the time and the correct form [nɔːn] 20.01% of the time. The intermediate group; on the other hand, were able to produce the correct form [nɔːn] at the higher rate of 79.99% of the time and the lower rate of the incorrect form [nɔːnɯ] 20.01% of the time. However, the correct form [nɔːn] was generated 100% of the time for the upper intermediate group.

***Table 13:** Production of Nasal stop variation in word-final position by Japanese speakers*

Word Stimuli		Beginner (J1-J5)	Intermediate (J6-J10)	Upper Intermediate (J11-J15)
Word-final	/tam/	[tamɯ] ~ [tam] 79.99% 20.01%	[tam] ~ [tamɯ] 66.66% 20.01%	[tam] 100%
	/nɔːn/	[nɔːnɯ] ~ [nɔːn] 79.99% 20.01%	[nɔːn] ~ [nɔːnɯ] 79.99% 20.01%	[nɔːn] 100%
	/yâːŋ/	[yaːŋɯ] ~ [yaːŋ] 79.99% 20.01%	[yaːŋ] 100%	[yaːŋ] 100%

As can be seen in Table 14, no nasal errors in the word-medial position were made by the English group, while nasals either became homorganic with the following consonant in word-medial position among the Japanese group, or vowel insertion was employed to break up the sequence of non-homorganic NC, as shown in Table 15.

***Table 14:** Nasals preceding stops in word-medial position by English speakers*

TOKENS	English native speakers			MEANING
	Beginner (E1-E5)	Intermediate (E6-E10)	Upper Intermediate (E11-E15)	
a. /tampuː/	[dambuː] 100%	[tʰampʰuː] ~ [dambuː] 50% 50%	[tampuː] 100%	‘papaya salad with crab’
b. /naḿtaː/	[namdaː] 100%	[namtʰaː] ~ [namdaː] 79.99% 20.01%	[namtaː] 100%	‘tear’
c. /tômkàj/	[domkàj] 100%	[tomkàj] ~ [tʰomkàj] ~ [domkàj] 33.34% 33.33% 33.33%	[tomkàj] 100%	‘boil chicken’
d. /săːmdɯːan/	[săːmdɯːan] 100%	[săːmdɯːan] 100%	[săːmdɯːan] 100%	‘three months’
e. /wɛ̂ntaː/	[wɛ̂ndaː] 100%	[wɛ̂ntʰaː] ~ [wɛ̂daː] 33.34% 66.66%	[wɛ̂ntaː] 100%	‘eyeglasses’
f. /kinpuː/	[kʰinbuː] 100%	[kʰinpʰuː] ~ [kinbuː] 33.34% 66.66%	[kinpuː] 100%	‘eat crab’
g. /kinkàj/	[kʰinkàj] 100%	[kʰinkàj] ~ [kinkàj] 79.99% 20.01%	[kinkàj] 100%	‘eat chicken’
h. /kaːŋkeːŋ/	[kʰaːŋkeːŋ] 100%	[kʰaːŋkeːŋ] ~ [kaːŋkeːŋ] 79.99% 20.01%	[kaːŋkeːŋ] 100%	‘pants’
i. /sɔ̌ːŋpiː/	[sɔ̌ːŋbiː] 100%	[sɔ̌ːŋpʰiː] ~ [sɔ̌ːŋbiː] ~ [sɔ̌ːŋpiː] 33.34% 33.33% 33.33%	[sɔ̌ːŋpiː 100%	‘two years’
j. /tɛ̀ŋtua/	[dæŋdua] ~ [tʰæŋtʰua] 66.66% 33.34%	[tʰætʰua] ~ [tæŋdua] ~ [tæŋtua] 33.34% 33.33% 33.33%	[tæŋtua] 100%	‘get dressed’
k. /sɔ̌ːŋbaj/	[sɔ̌ːŋbaj] 100%	[sɔ̌ːŋbaj] 100%	[sɔ̌ːŋbaj] 100%	‘two leaves’

***Table 15:** Nasals preceding stops in word-medial position by Japanese speakers*

TOKENS	Japanese Native Speakers			MEANING
	Beginner (J1-5)	Intermediate (J6-10)	Upper Intermediate (J11-15)	
a. /tampuː/	[tampuː] 100%	[tampuː] 100%	[tampuː] 100%	‘papaya salad with crab’
b. /naḿtaː/	[nandaː] 100%	[namɯtaː] ~ [namtaː] ~ [nantaː] 33.34% 33.33% 33.33	[namtaː] 100%	‘tear’
c. /tômkàj/	[toŋkàj] 100%	[tomɯkàj] ~ [tomkàj] ~ [toŋkàj] 33.34% 33.33% 33.33%	[tomkàj] ~ [tomɯkàj] 79.99% 20.01%	‘boil chicken’
d. /săːmdɯaːn/	[sǎːndɯːan] 100%	[săːmɯdɯːan] ~ [săːmdɯːan] 79.99% 20.01%	[săːmdɯːan] 100%	‘three months
e. /wɛ̂ntaː/	[wæntaː] 100%	[wæntaː] 100%	[wæntaː] 100%	‘eyeglasses’
f. /kinpuː/	[kimpuː] 100%	[kinɯpuː] ~ [kinpuː] ~ [kimpuː] 33.34% 33.33% 33.33%	[kinpuː] 100%	‘eat crab’
g. /kinkàj/	[kiŋkàj] 100%	[kinɯkàj] ~ [kinkàj] ~ [kiŋkàj] 33.34% 33.33% 33.33%	[kinkàj] ~ [kiŋkàj] 79.99% 20.01%	‘eat chicken’
h. /kaːŋkeːŋ/	[kaːŋkeːŋ] 100%	[kaːŋkeːŋ] 100%	[kaːŋkeːŋ] 100%	‘pants’
i. /sɔ̌ːŋpiː/	[sɔ̌ːmpiː] 100%	[sɔ̌ːŋɯpiː] ~ [sɔ̌ːŋpiː] 79.99% 20.01%	[sɔ̌ːŋpiː] 100%	‘two years’
j. /tɛ̀ŋtua/	[tæntua] 100%	[tæŋɯtua] ~ [tæŋtua] ~ [tæntua] 33.34% 33.33% 33.33%	[tæŋtua] 100%	‘get dressed’
k. /sɔ̌ːŋbaj/	[sɔ̌ːmbaj] 100%	[sɔ̌ːŋɯbaj] ~ [sɔ̌ːŋbaj] ~ [sɔ̌ːmbaj] 33.34% 33.33% 33.33%	[sɔ̌ːŋbaj] 100%	‘two leaves’

We see the pattern that before Japanese learners of Thai reached native-like pronunciation, they went through stages of acquisition. At the initial stage, they maintained their native phonology in producing the target word. Namely, the non-homorganic nasal-stop sequences -*mt*-, -*md*-, -*mk*-, -*np*-, -*nk*-, -*ŋp*-, -*ŋb*-, -*ŋt*- were adapted and produced as homorganic sequences -*mp*-, -*mb-,* -*nt*-, -*nd*-, -*ŋk*- as were required in their L1. But the English group did not exhibit place assimilation across syllables, just as they did not in their L1. Rather, they freely vary aspirated and voiced stops for an intended unaspirated stop in word-initial position at a rate of 66.66% and 34.34% respectively. The context-sensitive adaptation of consonants occurs when they did not have a direct correspondence in the English phonemic inventory to map onto the Thai phonemic inventory.

However, for Japanese intermediate learners, two consistent patterns of variation were found, (i) substituting with a homorganic nasal and (ii) vowel epenthesis to break up the non-homorganic sequence. At the final stage, learners correctly produced the non-homorganic nasal showing that the acquisition of nasals is complete.

To account for these acquisition generalizations, I assume the Gradual Learning Algorithm (GLA) approach proposed by Boersma (1997, 1999) and Boersma and Hayes (2001) where categorical variability comes from freely ranked constraints sacrificing parallelism. This paper attempts to provide an explicit formalization for the phonological variation and does not use standard OT assumptions. However, my analysis relies purely on raw data from the experiment corresponding from the lowest to the highest accuracies without having ranking values for constraints computed with input data by simulation.

3. Categorical Variability

According to standard OT assumption, the two candidates are differentiated according to their absolute violations resulting in the only one optimal candidate. (Archangeli & Langendoen 1997, McCarthy 2003, 2008). The constraints C1 and C2 are ranked at the top of the table, violations are shown via asterisks, and the pointing hand indicates the optimal candidate.

(16) Violation Tableau

	C1	C2
a. CANDIDATE A		*
☞ b. CANDIDATE B	*!	

However, when it comes to second language acquisition, variation in which one phonological input has variant forms of outputs (Anttila 2006) is common. Variation arises within or across an individual. It can also be either context free or context sensitive.

In section 3, I observe that both English and Japanese learners of Thai have two or three outputs for a single input. I also found the same pattern within the same participants, across the three separate days. The data also exhibit free variation in spread glottis and voice features of stops. In the case of Japanese learners, there is also nasal place assimilation to the place of a following consonant across syllables showing context-sensitive variation. These types of variation cannot be accounted for by the strict dominance ranking in standard OT. A categorical grammar is proposed instead having “freely ranked” constraints for different output forms.

Evaluation of the candidate set is split into two subhierarchies, each of which selects an optimal output. One subhierarchy has C1 >> C2, and the other C2 >> C1.

(17) Freely Ranked Constraints

/tôm/	*$_{\sigma}$[–voi, –SG	IDENT-IO(–SG)
a. [tôm]		
b. [t^{h}ôm]		

(18) Grammar One

/tôm/	*$_{\sigma}$[–voi,–SG	IDENT-IO(–SG)
a. [tôm]	*	
☞b. [t^{h}ôm]		*

(19) Grammar Two

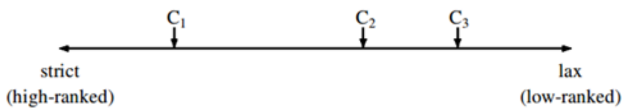
/tôm/	IDENT-IO(–SG)	*$_{\sigma}$[–voi, –SG
☞a. [tôm]		*
b. [t^{h}ôm]	*	

Grammar 1 results in a voiceless aspirated stop in word initial position while grammar 2 results in a voiceless unaspirated stop. These two stops contrast in terms of spread glottis. The distribution can be described by context-free condition.

As can be seen in the next section, the learners in the intermediate level produced two forms of output at an equal rate. An intermediate group of English speakers, for example, produced either voiceless aspirated or voiced stops at a rate of 66.66% of the time and 33.34% of the time respectively for Thai voiceless aspirated stops. The intermediate group of Japanese speakers either assimilated a nasal with the following consonant, or epenthesized a vowel to break up a non-homorganic nasal-stop sequence, at an equal rate. An OT analysis would run into a problem accounting for this free variation since the mechanism of fixed categorized constraints does not have room for constraint rearrangement within the same learner.

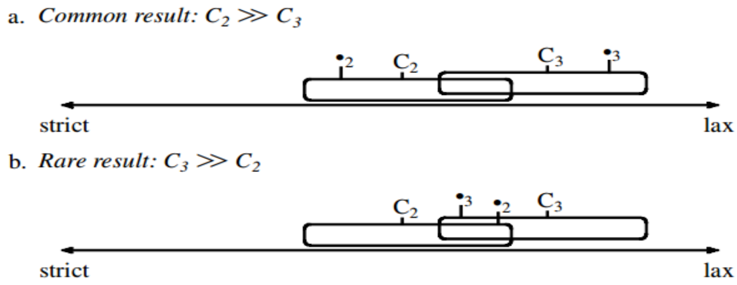
Boersma and Hayes (2001) propose another formalization called 'Stochastic OT', in which the constraints are arranged on a continuous scale of strictness, rather than a fixed range, as shown in (20). Each constraint is associated with a normal probability distribution. When evaluating, a point within the range is randomly chosen for each constraint. Constraints close to each other on the scale will overlap significantly resulting in optionality.

(20) Categorical ranking of constraints (C) along a continuous scale (Boersma and Hayes 2001)



From the above figure, the ranking is C_1 >> C_2 >> C_3 where >> represents domination. C_1 is highly ranked, and therefore is inviolable. C_1 strictly outranks C_2 and in turn C_2 strictly outranks C_3. By transitivity, C_1 outranks C_3. Note that C_2 and C_3 are less strict because the distance between them is relatively small. Though C_2 is less likely to overlap with C_1 due to their distance, it may overlap with C_3 due to the short distance between them. That leads to two possibilities that can happen on this scale. If the ranges covered by the selection points do not overlap, the scale simply shows the ordinary categorical ranking. However, if the ranges overlap, the ranking will be free. Free variation is possible because at evaluation time, it is possible to choose the selection points from anywhere within the ranges of the two constraints. The overlapping constraints are shown in (21) where the black dots represent the selection points for C_2 and C_3.

(21) Free ranking (Boersma and Hayes 2001)



The configuration in (21) illustrates the interlanguage development predicted and constrained by one grammar only where the two candidates have a range of selection points associated with their ranking value. When two constraints C_2 and C_3 are closely ranked with respect to their ranking values, there exists some overlap between them and this invokes a possibility where $C_3 >> C_2$ on the one hand and where $C_2 >> C_3$ on the other hand.

Under the Stochastic OT approach, we can account for second language acquisition assuming that, during the acquisition period, second language learners gradually acquire a different grammar, and continuously re-rank constraints as they progress to a higher level of proficiency. Each of the three stages is conceived of as an individual grammar i.e. as the grammar of an individual learner in each stage. In what follows, the experiment is presented and an analysis framed within a GLA version of OT is proposed.

4. Analysis of Production of Free Variation of Oral Stops by English Learners of Thai and Production of Homorganic Nasal Stops by Japanese Learners of Thai

4.1 Oral stop free variation in word-initial position

In order to account for oral and nasal stop production in different positions by English and Japanese learners of Thai, I propose categorical variability using "freely ranked" constraints which sacrifice parallelism and have evaluation split across variant outputs to account for variations in homorganic oral and nasal stops by English and Japanese leaners of Thai.

I introduce markedness constraints which have spread glottis [±SG] and [±voicing] features at the right edge of the prosodic word and at the left edge of the syllable as OT constraints.

(22) Markedness constraints
* $_\sigma$[–voi, –SG:
Assign one violation mark for every unaspirated voiceless stops in onset position.
* $_\sigma$[–voi, +SG:
Assign one violation mark for every aspirated voiceless stops in onset position.
* $_\sigma$[+voi:
Assign one violation for every voiced stops in onset position.

For my purposes, these markedness constraints are freely ranked and conflict with the faithfulness constraints.

(23) Faithfulness constraints
IDENT-IO(±SG):
Assign one violation mark for every input that has different values for the feature [±SG] from the output.
IDENT-IO(±VOICE):
Assign one violation mark for every input that has different values for the feature of [± voice] from the output.

English learners of Thai in the initial stage of acquisition produce two output forms: one weighing more than the other. Assuming categorical variability, Kager (1999:406) proposes that evaluation of the candidate set is split into two subhierarchies, each of which selects an optimal output. One subhierarchy has C1 >> C2, and the other C2 >> C1.

The rejection of voiceless unaspirated stops of the English group at the beginning level can be accounted for by the constraint ranking where markedness constraints override faithfulness constraints. In the early stage of grammars, the English learners of Thai vary in preference to either voiced stops or voiceless aspirated stops indicating $*_\sigma$[–voi, –SG is violated. In stage 1 grammar, the two constraints $*_\sigma$[+voi, $*_\sigma$[–voi, +SG which are freely ranked favor both candidates [kʰàj] and [gàj] as winners reflecting the actual frequency of occurrence. Note that stage 2 grammar has shown a slight preference to voiceless unaspirated stops (33.34%) resulting in ranking $*_\sigma$[–voi, –SG, $*_\sigma$[–voi, +SG rather than $*_\sigma$[+voi, $*_\sigma$[–voi, +SG as in grammar 1. In these two cases, the markedness constraints conflict with faithfulness constraints that militates against voiceless unaspirated stops.

English Learners of Thai

(*24a*) *Stage 1*: *Variant output forms* [*kʰàj*] (*86.67%*), [*gàj*] (*13.33%*)

		Freely Ranked			
/kàj/	$*_\sigma$[–voi, –SG	$*_\sigma$[+voi	$*_\sigma$[–voi, +SG	IDENT-IO(–SG)	IDENT-IO(–voi)
a. [kàj]	*!				
☞ b. [kʰàj]			*	*	
☞ c. [gàj]		*			*

(*24b*) *Stage 2*: *Variant output forms* [*kʰàj*] (*66.66%*), [*kàj*] (*33.34%*)

		Freely Ranked			
/kàj/	$*_\sigma$[+voi	$*_\sigma$[–voi, –SG	$*_\sigma$[–voi, +SG	IDENT-IO(–SG)	IDENT-IO(–voi)
☞ a. [kàj]		*			
☞ b. [kʰàj]			*	*	
c. [gàj]	*!				*

Tableau (24c) is different from that in (24b). The fatihfulness constraint IDENT-IO(–voi) is promoted while $*_\sigma$[+voi is demoted in stage 3 grammar. It is important that the faithfulness constraint dominates the markedness constraint. The candidate [gàj] is eliminated because of violation of the highest-ranking fatihfulness constraint IDENT-IO(–voi). Regardless of the participants' high proficiency of Thai, there exhibits variation in the production of stage 3 grammar. The two freely ranked constraints $*_\sigma$[–voi, +SG, $*_\sigma$[–voi, –SG are still active in the grammar, favoring two winning candidates [kàj] and [kʰàj] but in a lesser frequency displayed in the data for [kʰàj].

(*24c*) *Stage 3*: *Variant output forms* [*kàj*] (*79.99%*) [*kʰàj*] (*20.01%*)

			Freely ranked		
/kàj/	IDENT-IO(–voi)	$*_\sigma$[+voi	$*_\sigma$[–voi,+SG	$*_\sigma$[–voi, –SG	IDENT-IO(–SG)
☞ a. [kàj]				*	
☞ b. [kʰàj]			*		*
c. [gàj]	*!	*			

(25) English Learners of Thai
Stage 1 Grammar: $*_\sigma$[–voi, –SG, **$*_\sigma$[+voi, $*_\sigma$[–voi, +SG,** >> IDENT-IO(–SG) >> IDENT-IO(–voi)
Stage 2 Grammar: $*_\sigma$[+voi, **$*_\sigma$[–voi, –SG, $*_\sigma$[–voi, +SG** >> IDENT-IO(–SG) >> IDENT-IO(–voi)
Stage 3 Grammar: IDENT-IO(–voi) >> $*_\sigma$[+voi >> **$*_\sigma$[–voi, +SG, $*_\sigma$[–voi, –SG** >> IDENT-IO(–SG)

Japanese Learners of Thai

(*26a*) *Stage 1*: [*puː*] *(100%)*

/puː/	IDENT-IO(–SG)	IDENT-IO(–voi)	$*_\sigma$[–voi, +SG	*σ[+voi	$*_\sigma$[–voi, –SG
☞a. [puː]					*
b. [pʰuː]	*!		*		
c. [buː]		*!		*	

(*26b*) *Stage 2*: [*puː*] *(100%)*

/puː/	IDENT-IO(–SG)	IDENT-IO(–voi)	$*_\sigma$[–voi, +SG	$*_\sigma$[+voi	$*_\sigma$[–voi, –SG
☞a. [puː]					*
b. [pʰuː]	*!		*		
c. [buː]		*!		*	

(*26c*) *Stage 3*: [*puː*] *(100%)*

/puː/	IDENT-IO(–SG)	IDENT-IO(–voi)	$*_\sigma$[–voi, +SG	$*_\sigma$[+voi	$*_\sigma$[–voi, –SG
☞a. [puː]					*
b. [pʰuː]	*!		*		
c. [buː]		*!		*	

The ranking for Japanese participants are the same at all stages suggesting that they all were able to pronounce the target form. Therefore, the faithfulness constraints outrank the markedness constraints. The total contrast between English and Japanese learners of Thai is the different ranking in stage 1 and 2 grammar. The markedness constraint $*_\sigma$[+voi, $*_\sigma$[–voi,–SG and $*_\sigma$[–voi,+SG outranks the faithfulness constraint IDENT-IO(–SG) and IDENT-IO(–voi) explaining the quantitative generalization of learners' outputs with a preference +SG feature over –SG feature as in [kʰàj] 86.67 of the time for the stage 1 grammar and 66.66% of the time for the stage 2 grammar and only for [kàj] 33.34% of the time for the stage 2 grammar while the stage 3 grammar ranks in a different order between the faithfulness and markedness constraints to account for [kàj] 79.99% and [kʰàj] 20.01%. The faithfulness constraint IDENT-IO(–voi) ranks higher than the markedness constraint $*_\sigma$[+voi, which in turn ranks higher than the other two markedness constraints, which are freely ranked. The faithfulness constraint IDENT-IO(–SG) ranks the lowest. Some English speakers still were not able to produce voiceless unaspirated stops so they turn to their native sound which caused the errors.

(27) Japanese Learner of Thai at all stages
IDENT-IO(–SG) >> IDENT-IO(–voi) >> $*_\sigma$[–voi, +SG >> $*_\sigma$[+voi >> $*_\sigma$[–voi, –SG

4.2 Nasal stop free variation in word-initial and word-final position

Consider now the case of nasal stop free variants, where the intermediate and upper intermediate English learners of Thai generate more than one possible output for the same input. The Japanese did the same but with different sets of markedness constraints. The markedness constraint set between English in (28) and Japanese in (29) is different as follows:

(28) $*_w$[ŋ :
Assign one violation mark for words that begin with velar nasal stops.

(29) $*_w$[m >> *ŋ >> *n
Assign one violation mark for words that begin with bilabial, velar and alveolar nasals stops.

(30) Faithfulness constraints
IDENT-IO(PLACE):
Assign one violation mark for input that has different place of articulation from the output.
IDENT-IO(±NASAL):
Assign one violation mark for input that has different values for the feature of [± nasal] from the output.

The constraints in (28) disprefer the candidates with voiced velar oral or nasal stops in word initial positions. (29) contains a constraint set with a universal ranking for place of articulation proposed by Prince & Smolensky (1993) in which words that begin with labials are more marked than dorsals, which are more marked than coronals and glottals respectively (*[lab] >> *[dor] >> *[cor] >> *[glottal]). In this case, candidates with initial [m], [ŋ], [n] are assigned one violation.

English Learners of Thai

(*31a*) *Stage 1*: *velar nasal stop word initial output form* [*nuː*] (*100*%)

/ŋuː/	*ŋ	IDENT-IO(NAS)	IDENT-IO(PL)
☞ a. [nuː]			*
b. [ŋuː]	*!		
c. [guː]		*!	

(*31b*) *Stage 2*: *velar nasal stop word initial output forms* [*nuː*] (*66.66*%), [*ŋuː*] (*33.34*%)

		Freely ranked	
/ŋuː/	IDENT-IO(NAS)	*ŋ	IDENT-IO(PL)
☞ a. [nuː]			*
☞ b. [ŋuː]		*	
c. [guː]	*!		

(*31c*) *Stage 3*: *velar nasal stop word initial output forms* [*ŋuː*] (*79.99*%), [*nuː*] (*20.01*%)

		Freely ranked	
/ŋuː/	IDENT-IO(NAS)	IDENT-IO(PL)	*ŋ
☞ a. [nuː]		*	
☞ b. [ŋuː]			*
c. [guː]	*!		

(32) English learners of Thai

Stage 1 Grammar: *ŋ >> IDENT-IO(NAS) >> IDENT-IO(PL)
Stage 2 Grammar: IDENT-IO(NAS) >> ***ŋ, IDENT-IO(PL)**
Stage 3 Grammar: IDENT-IO(NAS) >> **IDENT-IO(PL), *ŋ**

As predicted, English beginners of Thai avoid *ŋ and yet are more faithful to nasality IDENT-IO(NAS). The candidates [ŋuː] and [guː] are ruled out. Alveolar nasal stops arise in order to avoid a velar word-initially. Thus, the faithfulness constraint IDENT-IO(PL) and *ŋ is freely ranked permitting [nuː] to surface. However, IDENT-IO(PL) is more faithful than *ŋ in stage 2 grammar but less so in stage 3 grammar as shown in Tableaux (31b) and (31c). The two constraints are overlapping constraints.

Preservation of nasality is more crucial in the English group, while for Japanese speakers, Tableaux (32a) and (32b) show that deletion of nasality is preferred, resulting in [guː] as one of the surface forms. I include one more losing candidate [muː] in Tableaux 32 so I invoke one more constraint in the constraint ranking which is *$_{w[}$m >> *ŋ >> *n forcing [nuː] to become a derived form along with [guː]. However, when *n, *ŋ IDENT-IO(NAS) are freely ranked, the variant [ŋuː] conforms better to the constraint *$_{w}$[m >> *n >> *ŋ and is able to surface as one of the winning candidate. To derive stage 3 of the grammar, faithfulness constraints are simply ranked over the markedness constraints.

Note that in stage 2 grammar the Japanese group preserves the place of articulation of the input form but violates IDENT-IO(PL). However, [gu:] incurs one violation of IDENT-IO(NAS) which is ranked low. The data suggests that at least two winning outputs are always available and generated in stage 2 grammar resulting free constraints ranking. Therefore, I predict that even the higher proficiency learners will have difficulty producing these words and will adapt them to accommodate their native phonology. The analysis is summarized in the following tableaux:

Japanese Learners of Thai

(*32a*) *Stage 1*: *velar nasal stop word initial output forms* [*guː*] (*66.66%*), [*nuː*] (*33.34%*)

			Freely Ranked		
/ŋuː/	*m	*ŋ	*n	IDENT- IO(NAS)	IDENT-IO(PL)
☞ a. [nuː]			*		*
b. [ŋuː]		*!			
☞ c. [guː]				*	
d. [muː]	*!				*

(*32b*) *Stage 2*: *velar nasal stop word initial output form* [*guː*] (*66.66%*), [*ŋuː*] (*33.34%*)

		Freely Ranked			
/ŋuː/	*m	*n	*ŋ	IDENT-IO(NAS)	IDENT-IO(PL)
a. [nuː]		*!			*
☞ b. [ŋuː]			*		
☞ c. [guː]				*	
d. [muː]	*!				*

(*32c*) *Stage 3*: *velar nasal stop word initial output form* [*ŋuː*] (*100%*)

/ŋuː/	IDENT-IO(NAS)	IDENT-IO(PL)	*m	*ŋ	*n
a. [nuː]		*!			*
☞ b. [ŋuː]				*	
c. [guː]	*!				
d. [muː]		*!	*		

(33) Japanese learners of Thai

Stage 1 Grammar: *m >> *ŋ >> ***n, IDENT-IO(NAS**) >> IDENT-IO(PL)
Stage 2 Grammar: *m >> ***n, *ŋ, IDENT-IO(NAS**) >> IDENT-IO(PL)
Stage 3 Grammar: IDENT-IO(NAS) >> IDENT-IO(PL) >> *m >> *ŋ >> *n

I propose another two constraints to account for the generalization for Japanese learners that vowel epenthesis occurrs to form a CV syllable for the stage 1 and 2 grammars surfacing as another variant output. The two constraints are:

(34) MAX-μ-IO:
Assign one violation mark for every input that has morae but not present in the output (no deletion).
DEP-μ-IO:
Assign one violation mark for every output that has morae but not present in the input (no insertion).

Japanese Learners of Thai

(*35a*) *Stage 1*: *velar nasal stop word final output forms* [*nɔːnɯ*] (*79.99%*), [*nɔːn*] (*20.01%*)

				Freely Ranked	
/nɔːn/	IDENT-IO(PL)	$*m]_w$	$*ŋ]_w$	$*n]_w$	DEP-μ-IO
☞ a. [nɔːn]				*	
b. [nɔːŋ]	*!		*		
c. [nɔːm]	*!	*			
☞ d. [nɔː.nɯ]					*

(*35b*) *Stage 2*: *velar nasal stop word final output form* [*nɔːn*] (*79.99%*), [*nɔːnɯ*] (*20.01%*)

				Freely Ranked	
/nɔːn/	IDENT-IO(PL)	*m]w	*ŋ]w	DEP-µ-IO	*n]w
☞ a. [nɔːn]					*
b. [nɔːŋ]	*!		*		
c. [nɔːm]	*!	*			
☞ d. [nɔː.nɯ]				*	

Given the fact that vowel epentheis is preferred the most in stage 1 grammar of Japanese learners of Thai, DEP-µ-IO is ranked the lowest. In the above tableaux (35a) and (35b), markedness and faithfulness constraints are freely ranked (*n]w >> DEP-µ-IO, DEP-µ-IO >> *n]w) to ensure both forms being the winning candidates and to reflect the quantitative data of the two variant outputs and higher frequency of the target output form. The candidates (b) and (c) do not conform with the place of articulation in the input form while the winning candidate (d) violates DEP-µ-IO by inserting a central unrounded vowel. The highest frequency of output therefore surfaces. However, the optimal output is driven by ranking faithfulness over markedness constraints in tableau (35c).

Since Japanese has /m/ and /n/ in onset position, it is more natural to turn word-final /m, n/ into a syllable onset, and therefore a vowel is inserted. As for /ŋ/, which does not appear in syllable onset position, the prediction is that vowel insertion is less likely to occur. Indeed, Japanese learners of Thai have a clear preference for the form produced with no vowel insertion [yaːŋ], not *[yaːŋɯ].

(*35c*) *Stage 3*: *velar nasal stop word final output form* [*nɔːn*] (*100%*)

			Freely ranked		
/nɔːn/	IDENT-IO(PL)	DEP-µ-IO	*m]w	*ŋ]w	*n]w
☞ a. [nɔːn]					*
b. [nɔːŋ]	*!			*	
c. [nɔːm]	*!		*		
d. [nɔː.nɯ]		*!			

(36) Japanese learners of Thai
Stage 1 Grammar: IDENT-IO(PL) >> *m]w >> *ŋ]w >> ***n]w, DEP-µ-IO**
Stage 2 Grammar: *m]w >> IDENT-IO(PL) >> *ŋ]w >> **DEP-µ-IO,*n]w**
Stage 3 Grammar: IDENT-IO(PL) >> DEP-µ-IO >> ***m]w, *ŋ]w, *n]w**

4.3 Homorganic nasal stops in word-medial position

As previously seen in Tables 14 and 15, English and Japanese learners of Thai have different preferences for different variant output forms. The English group does not show nasal place assimilation across syllable and word boundaries while assimilation was observed among the Japanese groups. Therefore, AGREE PLACE [NAS] is lowly ranked in the grammar of the English learners of Thai whereas it is required to be undominated to ban the candidate with heterorganic nasal-stop clusters in Japanese.

The idea is summarized in the following tableaux, which derive the two alternative outcomes for stage 1 and 2 grammars of English and three alternative outcomes for the stage 2 grammar of Japanese. Two more constraints are proposed to account for this generalization.

(37) AGREE PLACE(NAS) — Markedness Constraint
Assign one violation mark for every nasal that assimilates with the place of following consonant across either syllables or word boundaries.
IDENT-IO(PL) — Faithfulness Constraint
Assign one violation mark for every nasal that have different place of articulation form the output.

English Learners of Thai

(*38a*) *Stage 1*: *No homorganic nasal stops* [dæŋ.dua] (*66.66%*), [tʰæŋ.tʰua] (*33.34%*)

		Freely Ranked			
/tæ̀ŋ.tua/	IDENT-IO(PL)	*$_\sigma$[–voi, –SG	*$_\sigma$[–voi , +SG	*$_\sigma$[+voi	AGREE PLACE(NAS)
a. [tæŋ.tua]		*!*			*
b. [tæn.tua]	*	*!*			
☞c. [tʰæŋ.tʰua]			**		*
d. [tʰæn.tʰua]	*!		**		
☞ e. [dæŋ.dua]				**	*
f. [dæn.dua]	*!			**	

Note that the grammar here is consistent with the same ranking shown in tableaux (38a) and (38b). The two markedness constraints are overlapping (*$_\sigma$[–voi , +SG >> *$_\sigma$[+voi, *$_\sigma$[+voi >> *$_\sigma$[voi , +SG) deciding between the two candidates [tʰæŋ.tʰua] and [dæŋ.dua] because [tʰæŋ.tʰua] satifies *$_\sigma$[–voi whereas a candidate like [dæŋ.dua] satisfies *$_\sigma$[–voi , +SG. However, [tʰæn.tʰua] and [dæn.dua] are ruled out by IDENT-IO(PL) which is the highest-ranked constraint dominating AGREE PLACE(NAS).

As described, the English group produces the outputs that are more faithful to the input. And thus, the freely ranked markedness constraints determine the two winners of this tableau.

(*38b*) *Stage 2* : *No homorganic nasal stops* [tʰæŋ.tʰua] (*33.34%*), [tʰæŋ.dua] (*33.33%*), [tæŋ.tua] (*33.33%*)

		Freely Ranked			
/tæ̀ŋ.tua/	IDENT-IO(PL)	*$_\sigma$[+voi	*$_\sigma$[–voi , +SG	*$_\sigma$[–voi, –SG	AGREE PLACE(NAS)
☞ a. [tæŋ.tua]				**	*
b. [tæn.tua]	*!			**	
☞ c. [tʰæŋ.tʰua]			**		*
d. [tʰæn.tʰua]	*!		**		
e. [dæŋ.dua]		*!*			*
f. [dæn.dua]	*!	**			
☞g. [tʰæŋ.dua]		*	*		*

This production tableau has the same constraint ranking as tableau (38a). However, the English intermediate group stops producing voiced stops as shown in candidates (e) and (f) and thus *$_\sigma$[+voi constraint outranks *$_\sigma$[–voi , +SG, which in turn dominates *$_\sigma$[–voi, –SG but is capable of producing the target form in lesser frequencies as shown in the candidate (a).

At this stage, the English learners of Thai yield more forms of free variation in onset position as /tʰ/ or /d/ [tʰæŋ.tʰua] or [tæŋ.dua] for the input form /tæŋ.tua/. We would expect to find the two variations of [tæŋ.dua] and [dæŋ.tua] equally generated as the output form along with other variants. This is not the case since *[dæŋ.tua] is not attested. This might be because of the rather limited amount of data. If more participants had been recruited, [dæŋ.tʰua] might have been elicited as one of the surface forms. If it were an attestable output, it could not be derived. Only [tæŋ.dua] emerges as one of the winners. However, all surface forms have equal numbers of violations for all constraints. In stage 3, all English learners of Thai favor the same candidate [tæŋ.tua] so *$_\sigma$[–voi, –SG is ranked lower than the other two markedness constraints.

(*38c*) *Stage 3* : *No homorganic nasal stops* [tæŋ.tua] (*100*%)

/tæŋ.tua/	IDENT-IO(PL)	$*_{\sigma}$[+voi	$*_{\sigma}$[–voi , +SG	$*_{\sigma}$[–voi, –SG	AGREE PLACE (NAS)
☞ a. [tæŋ.tua]				**	*
b. [tæn.tua]	*!			**	
c. [tʰæŋ.tʰua]			*!*		*
d. [tʰæn.tʰua]	*!		**		
e. [dæŋ.dua]		*!*			*
f. [dæn.dua]	*!	*!*			
g. [tʰæŋ.dua]		*!	*		*

(39) The summary of the ranking constraints of no homorganic nasal stops of English learners of Thai.
Stage 1 Grammar: IDENT-IO(PL) >> *[**–voi, -sg,** $*_{\sigma}$[**–voi,** +**sg,** $*_{\sigma}$[+**voi** >> AGREE PLACE(NAS)
Stage 2 Grammar: IDENT-IO(PL) >> $*_{\sigma}$[+**voi,** *[**–voi,** +**sg,** $*_{\sigma}$[**–voi, –sg** >> AGREE PLACE(NAS)
Stage 3 Grammar: IDENT-IO(PL) >> $*_{\sigma}$[+voi >> *[–voi, +sg >> $*_{\sigma}$[–voi, –sg >> AGREE PLACE(NAS)

As can be readily observed from Table 15, non-homorganic NC sequences are problematic for Japanese stage 1 and 2 learners of Thai. Tableau 40 illustrates that all stage 1 learners generate 100% non-homorganic NC sequences incorrectly. The right optimal output will not surface because the stage 1 grammar chooses to satisfy AGREE PLACE(NAS). For the stage 2 grammar, vowel insertion was generated at equal frequencies of 33.33% of the time, competing with the candidate with nasal place assimilation and the target form. For stage 3 learners, non-homorganic nasals are generated 100% of the time.

This can be accounted for by the structure preservation constraint MAX-μ-IO which requires that all morae be present. AGREE PLACE(NAS) is also ranked high in stage 1 grammar. In stage 2, IDENT-IO(PL), DEP-μ-IO and AGREE PLACE(NAS) are freely ranked, [nammɯta:], [nanta:] and [namta:] all surface. As for the stage 3 grammar, a failure to meet the constraint ranking results in a fatal violation.

Japanese Learners of Thai

(*40a*) *Stage 1* : *Nasal place assimilation* [*nanta*:] (*100*%)

/nam᷇.ta:/	AGREE PLACE (NAS)	DEP-μ-IO	MAX-μ-IO	IDENT IO (PL)
☞ a. [nan.ta:]				*
b. [nam.mɯ.ta:]		*!		
c. [nam.ta:]	*!			
d. [na.ta:]			*!	

Only candidate [nanta:] can surface with this constraint ranking. The remaining candidates fail to satisfy this constraint.

(*40b*) *Stage 2*: *Vowel epenthesis* [*nammuta*:] (*33.34*%) [*nanta*:] (*33.33*%) [*namta*:] (*33.33*%)

		Freely ranked		
/nam᷇.ta:/	MAX-μ-IO	IDENT IO (PL)	AGREE PLACE (NAS)	DEP-μ-IO
☞ a. [nan.ta:]		*		
☞ b. [nam.mɯ.ta:]		*	*	*
☞ c. [nam.ta:]			*	
d. [na.ta:]	*!			

Explanations for which rankings leads to each produced output form are the following. Ranking DEP-μ-IO constraint the lowest ensures that the candidate [nam.mɯ.ta:] which is assigned a single violation will surface as the output form. AGREE PLACE(NAS) outranks IDENT IO(PL) favoring candidates with homorganic nasal stop clusters [nan.ta:]. This constraint is ranked high in a language that requires nasal place assimilation. On the other hand, a language that does not allow nasal assimilation, AGREE PLACE(NAS) is ranked low and is violable.

MAX-μ-IO does not favor candidates in which all syllables do not have the same number of morae as in the input [na.taː]. The faithfulness constraints take priority over markedness constraint in order for the participants to produce the optimal winner and the ranking constraints do the same in the stage 3 grammar.

(*40c*) *Stage 3*: *No hormorganic nasal* [*namtaː*] (*100%*)

/naḿ.taː/	MAX-μ-IO	IDENT IO (PL)	DEP-μ-IO	AGREE PLACE (NAS)
a. [nan.taː]		*!		
b. [nam.mɯ.taː]			*!	
☞ c. [nam.taː]				*
d. [na.taː]	*!			

(41) The summary of the ranking constraints of homorganic nasal stops of Japanese learners of Thai.
Stage 1 Grammar: AGREE PLACE(NAS) >> DEP-μ-IO >> MAX-μ-IO >> IDENT-IO(PL)
Stage 2 Grammar: MAX-μ-IO >> **IDENT-IO(PL), AGREE PLACE(NAS), DEP-μ-IO**
Stage 3 Grammar: MAX-μ-IO >> IDENT-IO(PL) >> DEP-μ-IO >> AGREE PLACE(NAS)

5 Summary

In this paper, I formalize the production grammars of L2 learners of Thai in the framework of Stochastic OT developed by Boersma and Hayes (2001) and show how the results support GLA predictions. This paper also illustrates the differences between L2 production grammar of English and Japanese Learners of Thai how they acquire different acquisition strategies. I focus on free variation based on probabilities of output forms. Markedness constraints are active at the initial stage of acquisition since learners are only familiar with their native phonology. As they gain more access to the grammar of a new language, they gradually become more faithful to the target grammar. This is where overlapping of constraints can explain variation. In this case, L1 markedness interferes and L2 markedness is not yet acquired. Once the learner becomes familiar with the new grammar, the faithfulness constraints become more dominant than the markedness constraints. This study shows that the frequencies of stage 2 learners of two competing forms can be accounted for via the multiple grammars theory of variation based on a continuous ranking scale.

It is noted that the present study did not report ranking values for the constraints, nor did it report the predicted probability of each variant. Providing quantitative measurements of the matching between the predictions of GLA and the experimental results was also beyond the scope of the present study. However, one of the utilities of GLA is its ability to make quantitative predictions. In future work, I would, therefore, suggest using either GLA or Maximum Entropy Grammar to account for probabilities of output forms obtained in experiments based on data of frequency and experimental results to model grammars with variation. However, this paper makes the correct prediction that L2 learners of Thai have different production grammars to the Thai sounds depending on their native phonology and on their level of L2 proficiency. And the proposed analysis would support cases of learners' interlanguage grammar as a grammatical system (Gass & Selinker 2008) not a stage but rather a full-blown grammar.

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